

Washington Department of Fish and Wildlife's High Lakes Fishery Management Program

Prepared for

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Prepared by

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ABOUT THE AUTHORS



Bob Pfeifer was the District Fish Biologist in the greater Seattle area for the Washington Department of Fish and Wildlife between 1978 and 2000. Prior to this he was a habitat biologist for the same area between 1972 and 1978. Mr. Pfeifer's management district contained approximately 670 lakes and ponds on lands managed by the US Forest Service, the Washington Department of Natural Resources, three large municipal watersheds (Everett, Seattle and Tacoma), and major timber owners. In addition to managing this large and diverse number of waters, Bob hiked to and surveyed most of those that support fish – many of them multiple times. He worked closely with other WDFW managers and members of the Trail Blazers and Washington State Hi-Lakers to develop an improved system for monitoring the fishery, and collaborated on the development of databases both inside and outside the agency. Pfeifer guided the development of Washington's only golden trout captive brood stock. He was the High Lakes Program Coordinator in the Seattle (Region Four) regional office between 1980 and 1999, coordinating the volunteer stocking and fishery monitoring over a 10-county area. Bob's passions are mountaineering, high lake fishing, and outdoor photography. He was the President of the Washington State Hi-Lakers for two years, and is currently the Treasurer of the Trail Blazers. (Bob is here seen in 1989 reveling in the awesome views from the summit of Three Fingers Mountain in Washington's North Cascades. The view is to the east over the Squire and Clear Creeks drainages.)



Mike Swayne has been a member of Trail Blazers, Inc. since 1958. An avid climber in his youth, Mike made a number of notable first ascents in the central and north Cascades. He has been a passionate and active hiker/mountaineer for over 40 years. Mike manages an environmental consulting business that develops databases for environmental projects specializing in the identification and remediation of hazardous and toxic chemicals at municipal, industrial, military and mining sites. As the long-time Librarian of the Trail Blazers, Mike has led the development of an extensive, comprehensive database on Washington's high lakes and fishery that would be the envy of most other state fishery agencies. The database identifies 3,837 high lakes and ponds in Washington with an associated 12,352 fish introductions and 11,403 fish observations. Mike acknowledges the assistance of the following agencies and organizations in developing this database: Trail Blazer library stocking and survey records; Hi-Laker library survey records; Snohomish County Sportsmen stocking and survey records; WDFW lake identification and stocking records in Olympia; WDFW regional biologist stocking and survey records; North Cascade National Park lake identification; biological and chemical survey records; Forest Service fish, wildlife, vegetation, and camp records; USGS chemistry records, StreamNet surface water topology records; and EPA chemistry records. (Mike is here seen in 1992 atop unnamed Peak 7722 in the Charlotte Alplands in the British Columbia Coast Range. The view is to the northwest.)



Brian Curtis has a degree in fisheries management, and has been a member of Trail Blazers, Inc. since 1987, and the Washington State Hi-Lakers since 1973. Like Mike Swayne, Brian maintains a powerful database on Washington's high lakes fishery, with an emphasis on trip survey reports. Brian and his father, Walt Curtis, are leaders in the development of lightweight backpacking and fishing equipment, some of which was indispensable in the collection of information presented in this report. (Their remarkable 20-oz pack raft is shown in its stuff sack in Plate 4, and in use in Plates 6, 11, 26, and 33.) Brian was the President of the Trail Blazers in 1994 and has served as the communications point of contact between the Trail Blazers and WDFW since 1997. (Brian is seen here on a recent [August 2001] trip to the Great Bear Wilderness in Montana. The view is over the Spotted Bear River towards the Bob Marshall Wilderness from Gunsight Peak.)

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This report is the result of the combined efforts of many people, spanning nearly three decades. The primary author's role was largely one of synthesizing the collective experience of others. Past and present WDFW fish biologists provided technical information contained within the report.

It would have been impossible to produce the report within the allotted time frame and budget without the *pro bono* contribution of time and database analysis by Dr. Mike Swayne of the Trail Blazers, Inc., and Mr. Brian Curtis of the Trail Blazers and the Washington State Hi-Lakers. The majority of the database information on the number of lakes, their size, stocking statistics, and volunteered angler reports was provided by these individuals. Their assistance and friendship is greatly appreciated. The Trail Blazer library was started by "Honest" Charlie Yadon soon after the club was formed in 1933. Charlie acquired his nickname due to his attention to detail and meticulous record keeping in log books, journals, annual reports, minutes, and notes from coordination meetings with the early Department of Game. Without his fine work much of the early years of Trail Blazer stocking efforts would have been lost to history. In more recent years the Trail Blazer library has been coordinated with Brian Curtis, the Washington State Hi-Lakers Librarian.

Figures 1 through 5, 6b through 7b, 14, 17, and Appendix K Plates 1 through 13 were prepared by Mike Swayne. All photographs were taken by the primary author unless otherwise noted. Many photographs or transparencies were freely given to the author over the years, and this was, again, sincerely appreciated. Individuals who were particularly helpful for this report include Gerry Ring Erickson, Jim Cummins, Larry Hirni, and Bill Henkel.

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Bob Pfeifer
September 16, 2001
Kirkland, Washington

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ACRONYMS

GPOs	Goals, Policies, and Objectives
HLS	High Lake System (Trail Blazer database)
NCNP	North Cascades National Park
NPS	National Park Service
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
WDFW	Washington Department of Fish and Wildlife
WDG	Washington Department of Game
WDW	Washington Department of Wildlife
WSP	Washington Salmonid Policy

EXECUTIVE SUMMARY

Report Purpose

This is the first comprehensive review and summary of the management of the high lake fishery in Washington State. Its purpose is to document the history, goals, and unique aspects of this program, as well as angler participation in, and economic value of the fishery. It identifies the number and general characteristics of the lakes that are managed for a fishery, as opposed to the many waters that are left in a natural state. The report provides documentation of the Washington Department of Fish and Wildlife's (WDFW's) current high lake management practices. WDFW seeks to increase public awareness and understanding of the high lake fishery program; this report documents how WDFW meets the public's need and desire for this form of recreation, while protecting other wildlife and wilderness values. Finally, the report is the first comprehensive preparation of recommendations on how to improve WDFW's high lake management program.

History

Most of Washington's high lakes were naturally fishless following the last glaciation. Native Americans may have placed some fish in some lakes, but early settlers, miners, and loggers carried trout fry into numerous lakes in the late 19th century. Prior to the creation of the Washington Department of Game by public initiative in 1933, management of fisheries in Washington's high lakes was conducted by the federal government (principally the Forest Service) and local county governments. Many lakes that currently contain problem (excessively abundant) fish populations received their initial introductions from these agencies and individuals, not the State of Washington. WDFW's progress in development and management of the fishery closely paralleled that seen in other states for the next 35-40 years. The performance of various strains and species of trout and char were empirically tested in waters of varying productivity and setting. Methods were developed and refined for stocking fry using backpack and aircraft to replace the old USFS pack strings or miners lugging milk cans. More rigorous methods were developed for surveying the lakes and their fisheries beginning in the early 1970s. Initial chemical treatments were made on high lakes to replace stunted, excessively abundant char with a controlled population of trout that is compatible with the alpine lake ecosystem. Methods were developed for more complete and error-free data collection, monitoring, database management, and reports.

Program Goals

WDFW's mission is Sound Stewardship of Fish and Wildlife; one of its goals in pursuit of this mission is "Maximum fishing, hunting and non-consumptive recreational opportunities compatible with healthy, diverse fish and wildlife populations". In general, conservative utilization is the objective for naturally-produced, native fish and wildlife populations. The high lake fishery is entirely artificial, created by stocking programs to provide a unique recreational fishing experience in Washington's subalpine and alpine environments. The goal of maximum recreational fishing opportunity is not inconsistent with the agency mission since management of the fishery is sensitive and responsive to issues such as genetic integrity of native fish populations, and irreversibly adverse ecological interactions with native vertebrates and invertebrates in and near stocked lakes.

Value of the Program

Only a handful of states in the coterminous United States have the diversity of landscape to offer recreational opportunity at thousands of lakes in subalpine and alpine environments, much of which is protected as designated wilderness. Washington has a rich glacial and legislative legacy of wilderness

settings that challenge the hiking angler, and provide a huge diversity of opportunity for angling of the highest quality. Users can choose destination lakes that range from the end of a road, to the most challenging remote locations that require a high degree of mountaineering skill to access. The fisheries include lakes that have supported family-oriented recreation for many decades. Depending on the lake setting and the individual, alpine lake fishing in Washington is often truly a unique experience.

The 1995 Angler Survey conducted by WDFW determined that more than 175,000 license-buying anglers fish Washington's high lakes annually. These anglers are in addition to children or others who, for one reason or another, do not purchase a license. About 1,400,000 fishing trips were made in 1994 by these individuals, based on an average of 7.7 trips per angler. Using an average figure of \$49.79 per trip yields an annual fishery value of over \$67 million. Because many of the high lakes support self-sustaining fish populations, and the cost of small fry used in stocking programs is very low, the program has a phenomenally high benefit to cost ratio of between 1000:1 and 1600:1. The high lake fishery is almost certainly the most cost-effective program administered by WDFW.

Lakes in the Program

Slightly over 4700 high lakes occur in Washington, based on a definition of their occurring above 2500 ft (mean sea level) west of, and 3500 ft east of the Cascades. Only 1777 (38%) of these support fish; of these, about 800 (17%) are periodically stocked. The balance, or about 1000 waters, have self-sustaining fish populations. Nearly two thirds (62%) of Washington's high lakes and ponds are fishless, and are broadly distributed across the landscape. Lake size and depth is highly variable, ranging in size from tiny ponds at about 0.1 acre, to very large lakes of over 300 acres. The majority are between 0.2 and 50 acres. The smallest lakes and ponds are usually at least 3 feet deep at their deepest point. Maximum depth increases continuously with lake size up to about 160 acres. A typical 10-acre lake would have a maximum depth of about 40 feet. There is great diversity in average depths, shoreline shape and slope, setting, exposure, soil development, and bedrock type, resulting in a wide range of potential productivity.

Many of the lakes contain excessively abundant populations of eastern brook or cutthroat that are known to have adverse effects on native biota in or near the lakes. Determining an accurate list of these lakes, the problem species, the lake locations, and the most practicable treatment for each water was beyond the scope of this report, but is a very important next step. Local WDFW fishery managers are, for the most part, well aware of most of these lakes, but some field reconnaissance may be necessary to derive a fully complete list since not all lakes have been surveyed in a few locations.

Current Management

Great progress has been made by WDFW biologists in performing "baseline" surveys on waters under their responsibility, but the task is not yet complete. Physical, chemical, and biological survey methods were developed primarily in the early 1970s, but a formal state-of-the-art Methodology, or Methods Manual for high lake surveys has not been prepared. This should be considered a high priority, as well as providing the human and other resources needed to implement it, and complete the surveys. This report describes some of the major elements of such a Methodology.

A large amount of data has been collected on the lakes (physical and chemical characteristics), and on the biology of the fish and invertebrates within them. Work was initiated on developing a model of trout growth or lake productivity in a subset of Washington high lakes. This work should be completed by adding the data collected by WDFW biologists in other geographic areas. The results of this analysis should not, and probably cannot provide a cookbook or prescription for individual lake management, but would be of great value by increasing technical understanding of the production capabilities of lakes or lake types in Washington.

Local WDFW biologists visit their lakes on a time-available basis, but monitoring of the fishery is largely volunteer-based. This is developed to an usual degree in Washington, particularly with two key sports clubs in the Seattle area. The Trail Blazers, Inc., founded in 1933, and the Washington State Hi-Lakers were leaders in the development of data forms and methods to systematically collect and organize information on fishery performance at the remote lakes. WDFW has worked closely with these groups for many years, and relies heavily on their input to track program success. WDFW needs to allocate additional local staff time to maintain this feedback mechanism. Use of the Internet should be explored as a way to expand the sources of angler information, but there is no substitute for the experience of the local professional fishery manager in filtering and managing volunteer-based information.

While data management has improved greatly since 1972, some staff time (temporary or permanent) needs to be devoted to closing data gaps and correcting (relatively minor) data flow problems. The most important need is to develop a consistent approach to collecting and managing volunteered monitoring data, and producing periodic report summaries to enable routine management decisions.

The discipline in Washington's stocking program is its hallmark. Knowledge of fish reproductive status in each lake under management is critical information. WDFW managers have determined this for most, but not all lakes under management. Stocking schedules are generally not set on any lake for which fish reproductive status is not known. Resources need to be directed at lakes and counties where this information is most needed (e.g. Chelan County). An even higher level of discipline could be achieved if measures of natural and angling mortality of trout were available. These measures should be obtained for several fish species, in a variety of settings, and under a range of fishing pressure. This information would be an extremely valuable adjunct to the volunteer-based monitoring program.

Recreational overuse at lakes, particularly in wilderness areas, is usually not caused solely by anglers. Angling is rarely the primary activity at lakes where overuse is a serious problem. WDFW should continue to work cooperatively with land managers on overuse issues, but not terminate stocking as a means of controlling human numbers at lakes. Controls on access (e.g. limited entry, or the distance people must walk) are a far more equitable and effective means of reducing use levels.

Experience and research has shown that most high lakes in Washington need not, and should not be stocked at densities greater than 50 to 100 fish per surface acre. WDFW managers became aware of this fact years before issues surrounding the decline of amphibians came to light. To prevent excessive fish numbers in a lake, trout or char species and strains should be, and are chosen that have a demonstrated inability to successfully reproduce in a given lake environment. Research on the use of sterile hybrid crosses and strains proceeds on the basis of time and financial resources availability. Overall stocking has been declining for 20 years, as well as the average density of fish stocked. Most lakes that require stocking are on low-density maintenance programs.

New fish species or strains are not stocked into waters they have not been stocked into previously without appropriate review of the biological effects. At the same time, WDFW managers need to be given the freedom to use special strains under carefully prescribed circumstances. An example is the use of top predators such as tiger muskellunge as a biological control of stunted eastern brook trout. WDFW local managers give full consideration to the potential effects of fish introductions on downstream native fish resources, and this will continue.

As a general rule, species should be, and are stocked that are native to the lake's drainage basin. However, to meet the program goal of providing diversity in the fishery, strains that are not having a negative effect on native biota should continue to be stocked (e.g. golden trout). Other strains or species should be stocked where it makes sound biological sense to do so, such as where biological controls are used to control excessive fish abundance, rather than the use of piscicides.

WDFW is aware of the need to practice ecologically responsible stocking in the high lakes. To this end, the prioritized research topics identified in the literature review conducted concurrent with this report preparation should be implemented as budgets allow. Fish should be removed from lakes where they are documented to have an unacceptable impact on native species. However, the results of studies in other states should not be categorically applied to Washington where invertebrate and amphibian communities and ecological relationships often differ from those of the states where other research occurred.

Earlier mistakes made by individuals and agencies that resulted in self-sustaining, excessively abundant trout or char populations in some Washington high lakes can be rectified in many cases. A list of prioritized lakes needing fish population control should be prepared. The extremely high benefit to cost ratio of this program should be balanced against the cost of a long term program of lake reclamations. Annual conversion of several high lakes to quality, low-density trout fisheries will go far towards meeting future recreational demand, will increase angler satisfaction, and will systematically reduce the impacts of overabundant fish on native biota. The most practical control option for each lake should be identified. To date only chemical treatment has been shown to eliminate stunted, overabundant fish in Washington high lakes. Biological controls show considerable potential for reducing fish abundance; further testing in Washington is warranted on lakes where other methods are impractical. Spawning area exclosures and intensive netting or fishing may have some potential in a limited number of lakes.

The demand for recreational fishing continues to rise as the population of Washington increases. WDFW local managers have learned through painful experience that when historic fish populations are allowed to die out in lakes, unscrupulous publics will sometimes reintroduce fish. The illegal re-introduction may not be a suitable species, and may cause irreversible harm. The number of lakes being managed for low-density, high quality fisheries should not be allowed to drop below current levels in order to satisfy recreational fishing demand, and to demonstrate active, responsible management.

Periodic angler use surveys such as was conducted in 1995 should continue. Given the value and cost-effectiveness of the high lake fishery, it should be given special attention in future surveys.

WDFW has a long history of cooperation with major state, private, and federal land managers. Periodic or annual meetings to discuss mutual management issues should be encouraged. The 1988 Supplemental Agreement to the memorandum of Understanding between WDFW and the National Park Service should be renegotiated. It should take advantage of the best current science, this report, the concurrent literature review, and the corporate experience of groups such as Trail Blazers, Inc.

Public outreach and education can be increased by broad publication of this report and other media explaining the high lake program. This report and the associated literature review should be made available on the agency website. Local WDFW managers need to be given the time to maintain, or increase their communication with publics and groups that supply needed feedback and fishery monitoring.

What Have We Learned

WDFW understanding of management of the state's high lake fishery can be summarized as follows:

- Continue to not stock all available waters. Balance ecological issues with fishery values. Maintain a network of barren lakes and ponds across the landscape.
- Stock only at low densities.
- Avoid species and strains that may reproduce excessively.
- Remove or reduce problem fish populations wherever it is feasible to do so. Replace excessively abundant species with a controlled fish community to meet the public demand for this form of recreation.
- Stock native species primarily. Contain stocked fish to the target lake by use of appropriate stocking methods.
- Maintain close coordination with other land managers.

Research

Studies specific to Washington would be valuable that addressed subjects investigated in other regions, such as identification of the stocking densities and intervals that have significant, or irreversible impacts on native invertebrates. More complete information is needed on the basin life history and abundance of amphibians in Washington's high country; to date there is no evidence that any species native to this life zone is severely depressed or endangered.

More definitive information is also needed on the degree to which stocks used by WDFW emigrate or drop out of lakes in which they are stocked.

1. INTRODUCTION

1.1 REPORT BACKGROUND AND PURPOSE

Many people do not understand the high lake fishery program that has been managed by the State of Washington since 1933. Ignorance and misunderstanding has resulted in published misinformation, even by fisheries professionals. Few people understand that nowhere near all mountain lakes in Washington are being stocked, or even contain fish, and that the number of lakes being stocked, as well as trout stocking densities, have been steadily dropping for years. Many do not know that the stocking program is now basically one of low-level maintenance of quality trout fisheries, wherever possible. Many, perhaps most license-buying angler-hikers do not know how trout came to exist in mountain lakes, or how they are managed. Members of some groups whose mission is to protect wilderness areas and wilderness values believe trout have no place in wilderness lakes. Many do not know of, or understand the effort Washington Department of Fish and Wildlife (WDFW) fishery managers take to coordinate the high lake trout program with other land and wilderness management agencies.

This report, along with a comprehensive scientific literature review (Divens et al. 2001), was prepared as one mechanism to dispel myths and misunderstandings related to WDFW's trout management in high lakes. It will better educate the public on the methods WDFW uses to manage the fishery, and to co-manage aquatic habitats in a way that is beneficial to recreational users, yet has minimal impact on the natural environment. It describes the major economic and recreational benefits of the fishery in perspective relative to its ecological impact.

The need for a written, standardized methodology for the survey and management of high lake trout fisheries has been recognized by WDFW biologists for years. This report is a step towards that goal, although it is not intended to be a thorough technical reference document for current and future field and office management biologists. The primary purpose and objective of this report is to describe WDFW's current approach to high lake fishery management statewide. Management methods vary somewhat around the state, as do geography, geology, climate, lake environments, and angler use levels. This report identifies and explains the overall management approach, and the reasons for differences among WDFW administrative regions.

This report is not a future Management Plan for Washington high lakes. It is not intended to be a prescription of the methods and policies that will shape these fisheries in the future, however it does identify management principles which have shown success or promise in recent years. The purposes of this report are as follows:

- Document the history, goals, objectives, and unique aspects of the high lake program in Washington State;
- Document angler participation and economic value of the fishery;
- Identify the number and general characteristics of high lakes managed for a fishery;
- Document WDFW's current high lake management practices;
- Inform and educate the public on the high lake program, and the steps being taken to balance mandates; and

- Recommend modifications to improve the high lake management program in Washington.

1.2 REPORT PREPARATION METHODS

For the purposes of management and this report, WDFW fishery managers have defined a high lake in western Washington as one situated above 2500 feet (762 m) mean sea level (msl), and above 3500 feet (1,067 m) msl in eastern Washington (Figure 1). These elevations are not wholly arbitrary, but take into account the location of the sub-alpine and alpine zones, as well as other attributes. Since the alpine zone lies well above 2500 ft msl in western Washington, the term “high” lake is preferred over “alpine” lake, as the former is more inclusive.

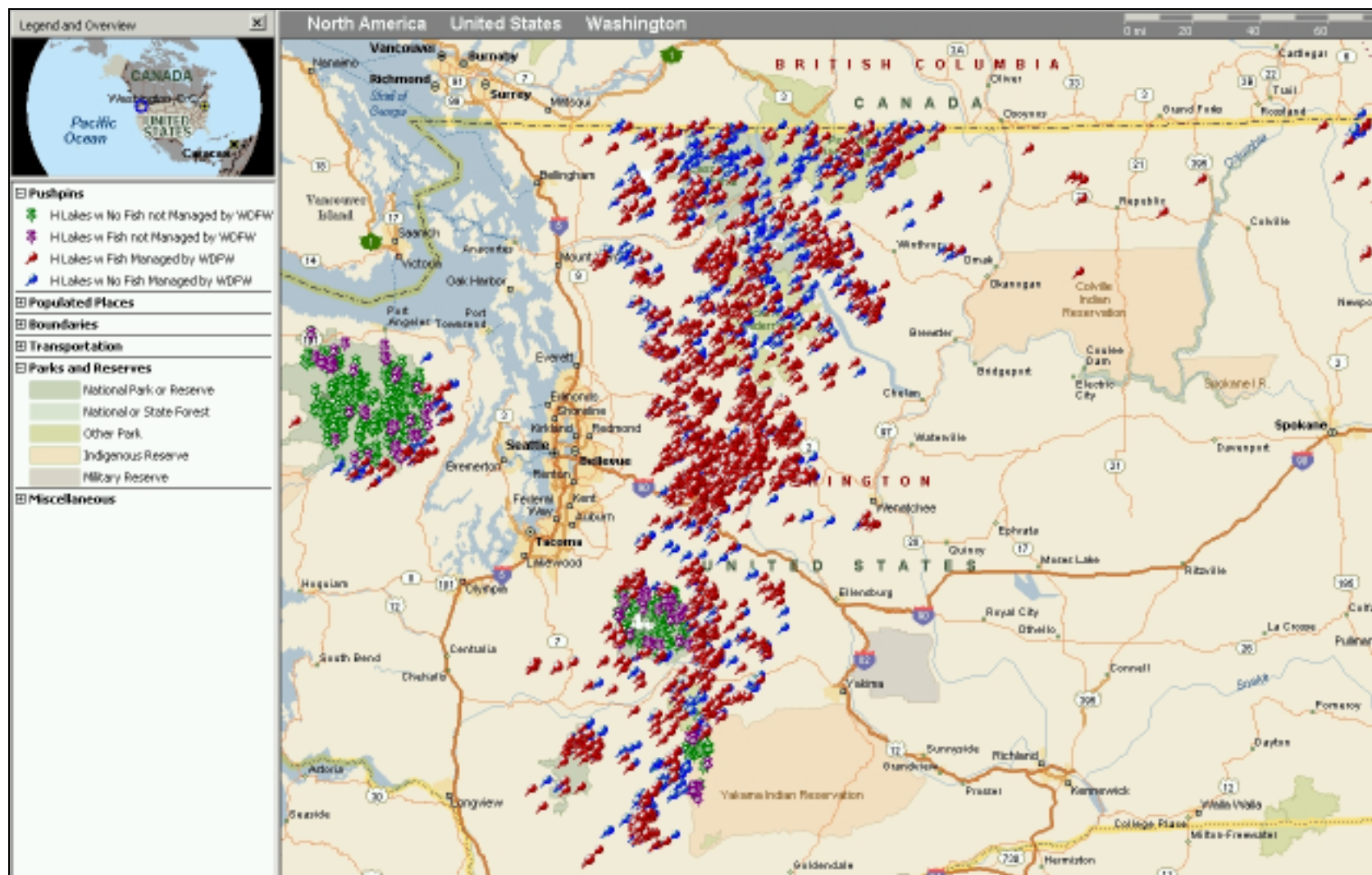
Most “high” lake fisheries, as defined, are managed much differently than lowland lake fisheries. The actual difference in management approach is more pertinent than strict elevation in many cases. Some, perhaps most local WDFW fishery managers pay little or no attention to lake elevation, but set stocking frequency and density, and make fish species selections based more on factors such as access, lake productivity, and anticipated angler use levels. “High lake” fisheries are generally managed for low fish density, low angler use levels, and higher “quality” fishing opportunity than most lowland lakes.

Definition of a high lake “universe” was required to prepare this report. The initial data set was prepared using the 2500 ft / 3500 ft breakout for western and eastern Washington, respectively, and subset files were distributed to each WDFW local manager for an accuracy check. A few lakes located below these elevations were added due to their management approach and local environmental conditions. Conversely, a very small number of waters above these elevations were removed from the sets for various reasons. The agreed upon files for each district were used to generate the statistics used in this report, and were closely coordinated with the Trail Blazer High Lake System (HLS) database (below).

Much of this report’s content is based on the primary author’s 20+ years of experience in managing high lakes in the central and north Cascades, and intimate familiarity with the program’s internal processes of lake surveys, trout culture, stocking, monitoring, and database management. An important step in the coordination and collection of statewide information occurred during a 2-day meeting in Wenatchee on January 17-18, 2001 of current and recently-retired district fish biologists. A comprehensive questionnaire was prepared to guide discussion and collection of information (Parametrix 2001). Detailed discussion of the questionnaire’s content occurred at the January workshop. Later, all attendees, plus several who could not make the workshop, completed the questionnaire, giving concise, and often frank answers. These were subsequently compiled within the questionnaire format, with individual local management biologist comments listed below each question.

The importance and value of the 2-day workshop was critical in development of this report. Subtle differences in regional program implementation that may be suggested by dry stocking records from a central database often have sound reasons, based on local conditions. Many of the management biologists who attended the workshop or completed the questionnaire had, or have 20-27 years of practical field experience in managing high lake fisheries (Appendix A). As a group, the respondents represent more than 150 years of field experience with high lake fisheries in Washington’s Cascades and Olympic Mountains. This report seeks to capture the value of that extensive field and management experience. Much of the commentary in succeeding report sections follows directly from the workshop and compiled managers’ responses.

Figure 1 The Distribution of High Lakes and Ponds in Washington State. Blue lakes are those WDFW-managed waters >.1 acres without fish stocked or seen. Red lakes are those WDFW-managed waters where fish have been stocked or seen.



Some of the most critical statistics in this report that appear in charts and tables were prepared using the Trail Blazer HLS database. This database has been developed over the last 20 years by combining data from several sources including: Trail Blazer library stocking and survey records; Washington State Hi-Laker library survey records; Snohomish County Sportsmen stocking and survey records; WDFW lake identification and stocking records in Olympia; WDFW regional biologist stocking and survey records; North Cascade National Park lake identification; biological and chemical survey records; US Forest Service fish, wildlife, vegetation, and camp records; USGS chemistry records, StreamNet surface water topology records; and EPA chemistry records.

The HLS contains 4,718 high lakes and ponds, and contains essentially all the high lakes and ponds shown on USGS 1:24,000 scale topographic maps in Washington. These maps show essentially all lakes and ponds greater than about 0.2 acre. Coverage in the North Cascades National Park is more complete and includes several lakes and ponds identified from aerial and ground surveys in the 0.1-0.2 acre size range, with a few identified down to the 0.03 acre size. The HLS contains 12,140 high lake fish stocking records and is considered reasonably complete from the early 1930's to 2000, with some records going back to 1914, and a few back to 1899. It also contains 11,400 fish survey and observation records and is considered reasonably complete for WDFW Region 4.

2. HISTORY

2.1 PRE-1933

Most high lakes in Washington's Cascades and Olympics were created following the last glaciation, roughly 10,000 years ago (Bretz 1913, 1915; Booth 1987). Whether lakes were created by glacial plucking of the bedrock, or by other processes such as avalanche damming of stream valleys (Hutchinson 1975), the newly-created lake basins would be barren of fish unless fish had access from the sea or streams draining the landscape as the ice masses retreated. Most high lakes have steep gradient outlets or outlet falls which are total barriers to upstream movements of fish into the lake. However, a few high lakes in Washington did retain native fish populations following the Pleistocene glaciation. These are very few in number, and are located in headwater areas of 2nd or 3rd-order streams (e.g., Waptus Lake in Kittitas County).

Since a search for isolated documentation of fish presence in high lakes at the time of European colonization of the Pacific Northwest was beyond the scope of this report, the actual extent of natural fish presence in high lakes of Washington is largely a matter of speculation. Early trappers, miners, loggers, and outdoorsmen would be expected to carry a few trout fry (juvenile fish up to 1.0 inch [Lagler 1952]) from local streams to stock lakes near their cabins or workings to provide a ready source of protein or recreation. Regardless of how or why the practice began, stocking of high lakes by the packing of fry was well underway, even officially sanctioned, by the early 20th century. Rief (1906) describes fish caught from Lake Calligan, near North Bend, in King County – a lake that was created by damming of a steep tributary of the North Fork Snoqualmie River by the moraine of a valley glacier. Rief (1906) makes note of trout up to 10 pounds in Calligan, as well as the presence of a single miner's cabin on the lake. Many lakes throughout Washington were stocked with U.S. Forest Service (USFS) mule pack trains. WDFW file records document USFS introductions of kokanee salmon (*Oncorhynchus nerka*), eastern brook trout (*Salvelinus fontinalis*), and cutthroat trout (*O. clarki*) into Seattle-area high lakes as early as 1914. This practice was not unique to the United States (Donald 1987).

Local fish and wildlife resources were managed by the various counties prior to 1933. For example, King County wildlife officials managed fish traps on local streams, including the outlets of some high lakes, to collect spawn for supplementation purposes. Dorothy Lake, a high lake located near Skykomish, in King County, was stocked with eastern brook trout in 1921 and 1922 (Piper and Taft, Inc. 1925). Spawn was collected from this lake, as well as Lake Hancock, near North Bend prior to creation of the Washington Department of Game by public Initiative in 1933. Many lakes in the Cascades and Olympics had already received their initial fish introductions prior to the creation of the agency which has had the responsibility of their management since 1933.

Significant ecological impacts associated with excessive trout abundance in some high lakes are the direct result of unknowing mistakes made by early non-governmental parties, as well as federal and county agency staff. Many of the stunted eastern brook trout populations in Washington high lakes were created by introductions that occurred in this early era.

2.2 1933 TO 1971

From its inception in 1933, the Washington Department of Game (WDG) continued the stocking programs begun by the USFS and the counties. However, no detailed documentation exists of the guidelines (if any) used by state inland fisheries biologists in making species or stocking density decisions. Examination of the historical stocking record (Section 5.3.1) shows that relatively high

stocking densities were the rule more than the exception, with levels of more than 1000 trout per surface acre occurring frequently.

At about the same time as the creation of the WDG, a group of sportsmen keenly interested in Washington's high lake fishery was organized in Seattle (Yadon et al. 1993). While sports club coordination with the new agency was, and still is commonplace, the Trail Blazers, Inc. were unique in their focus on the development of the high lake fishery. Stocking by the club and interaction with agency biologists tended to be focused on lakes in the west central Cascades initially, but later expanded to most counties with high lakes (Appendix I). Close coordination occurred in the development of new stocking methods, which has continued to this day. Agency fish biologists worked with the club to design biological survey techniques and data forms. Work parties were organized in the 1930s and 1940s to conduct first-time biological surveys of some high lakes, prior to any fish introductions. This level of coordination still continues.

Organized angler interest led to the stocking of some trout species or strains exotic to Washington. These include golden trout (*Oncorhynchus aguabonita*) from California, and Kamloops rainbow (*O. mykiss*) from British Columbia. The earliest golden introductions occurred in King County in 1936 in several lakes in the current Alpine Lakes Wilderness Area. The earliest recorded stocking of Kamloops rainbow occurred in Chelan County in 1932. There have been no biological problems associated with the low-density stocking of golden trout, but Kamloops rainbow are often successful at reproducing in Washington's high lakes. A number of stunted rainbow populations have developed from these early Kamloops introductions.

Scientific understanding of the limnology of Washington's high lakes, and the ecological effects of the trout program on the lake communities made very slow progress in these four decades. Biologist managers, who were very low in number and had very large districts, devoted what time they could to the fishery, but little in-depth analysis occurred, or could occur, given staff and equipment constraints. Most lakes were stocked for the sole purpose of providing recreational fishing opportunity, and little detailed attention was paid to the fine points of lake and fish population management. Most stocking programs were developed through trial-and-error. Species or strains later found to reproduce excessively continued to be stocked in some lakes, but by the 1950s it was recognized that some species, such as eastern brook trout, could overpopulate lakes and create stunted, low-quality fish populations.

A number of very significant developments occurred in the post-War era. The first of these was the development and broad use of High Lake Report cards in about 1955 - franked postcards on which anglers could provide postage-paid feedback to the agency management staff on conditions observed at lakes they visited (see Section 5.2 and 5.3.2). A second was the development shortly after WWII of fry stocking methods using fixed-wing aircraft. A high degree of piloting skill was acquired by one or two tenured agency pilots who had a keen interest in this stocking technique (Clayton Barnes, Tom Wilson). Third, agency staff biologists, and groups such as the Trail Blazers, began to realize that higher quality trout populations and greater success in stocking (fry survival) could be achieved through reduced stocking densities and stocking frequencies.

For much of this era the Trail Blazers were a *de facto* right arm of the WDG Fisheries Management Division for management of the high lake fishery. Stocking recommendations proffered by the club were usually approved without much discussion, and the club made material progress in evaluating the relative performance of several trout species and strains, and reduced stocking densities. The benefits of their experience were conveyed to the agency staff through frequent written communications, and during the coordination of annual stocking plans. Although this club's activities did not blanket the Cascades and Olympics, they were active in a large percentage of this area (Figure 1; Appendix I), and their findings

and recommendations affected management decisions made in other areas of the state. For the most part, the WDG approved stocking requests made by sports groups during this era.

The incremental addition of lakes to the list of those being stocked for recreational fishing occurred slowly at first due to access difficulty. As road construction for logging and other purposes increased in the 1940s and 1950s, the number of lakes added per year also increased (Figure 2). The number of new lakes being stocked peaked in 1940, and has since been in general decline. Most “new” waters stocked in the late 1970s and throughout the 1980s were almost universally small, remote waters that may have actually held fish in the past, but for which no disciplined stocking history had been initiated. Since 1991 few to no lakes that had no previous stocking history have been added to the list of lakes being stocked.

The annual number of high lakes stocked (disregarding whether they have been stocked in the past) is shown in Figure 3. This number peaked in 1988, and has also been in general decline for the past 12 years. Reasons for removing lakes from the stocking program are discussed in Section 5.4.2.3.

The use of mule or horse pack trains to stock high lakes diminished in this period, being largely supplanted by back packing of fry, and the use of aircraft, both fixed-wing and helicopter. The agency only recently discontinued horse packing in the Methow River basin in north central Washington, but low-level recreational horse packing of trout fry continues in several areas of the central and south Cascades. This is usually accomplished by members of the Backcountry Horsemen, but the USFS continues this tradition in some areas in Washington. As with the Trail Blazers, these volunteer-based activities were closely coordinated with the agency in the development of annual fry stocking allotments.

2.3 1972 TO DATE

The following section, which describes Washington’s high lake fishery management since 1972, is a concise summary of the principal developments in the management of this fishery in the last 29 years.

Lake Surveys

The most significant milestone in the history of high lake management in Washington was the hiring of a group of fish biologists around 1970 who took a keen, active interest in the scientific development of the management of this fishery (Appendix Plate 1). 1972 was chosen as a break point in time since that was the year when the first technical reports were prepared that led directly to significant changes in management approaches. Unusual freedom and support was given to several of these district biologists, who devoted the summers of up to 3 or 4 years of their early careers to the relatively intense survey of lakes within their geographic areas of responsibility. (The late Cliff Millenbach, Chief of the Fisheries Management Division of WDG, is gratefully acknowledged for his support and encouragement of these directed studies.) A number of technical reports were produced (Cummins 1972, 1973, 1974, 1975; Johnston 1972, 1973; Williams 1972, 1975, 1976). These reports, along with workshop-like discussion at annual WDG biologist meetings, led to further refinement of data collection and lake survey methods, as well as a general reduction in stocking densities (Figure 4) and stocking frequency (Figure 5). Contrary to published misinformation (e.g., Bahls 1992), Washington fishery managers have been well aware of the need to control trout abundance in high lakes for at least 25 years.

Figure 2. The Number of New Washington High Lakes Stocked, by Year, 1914 – 2000.

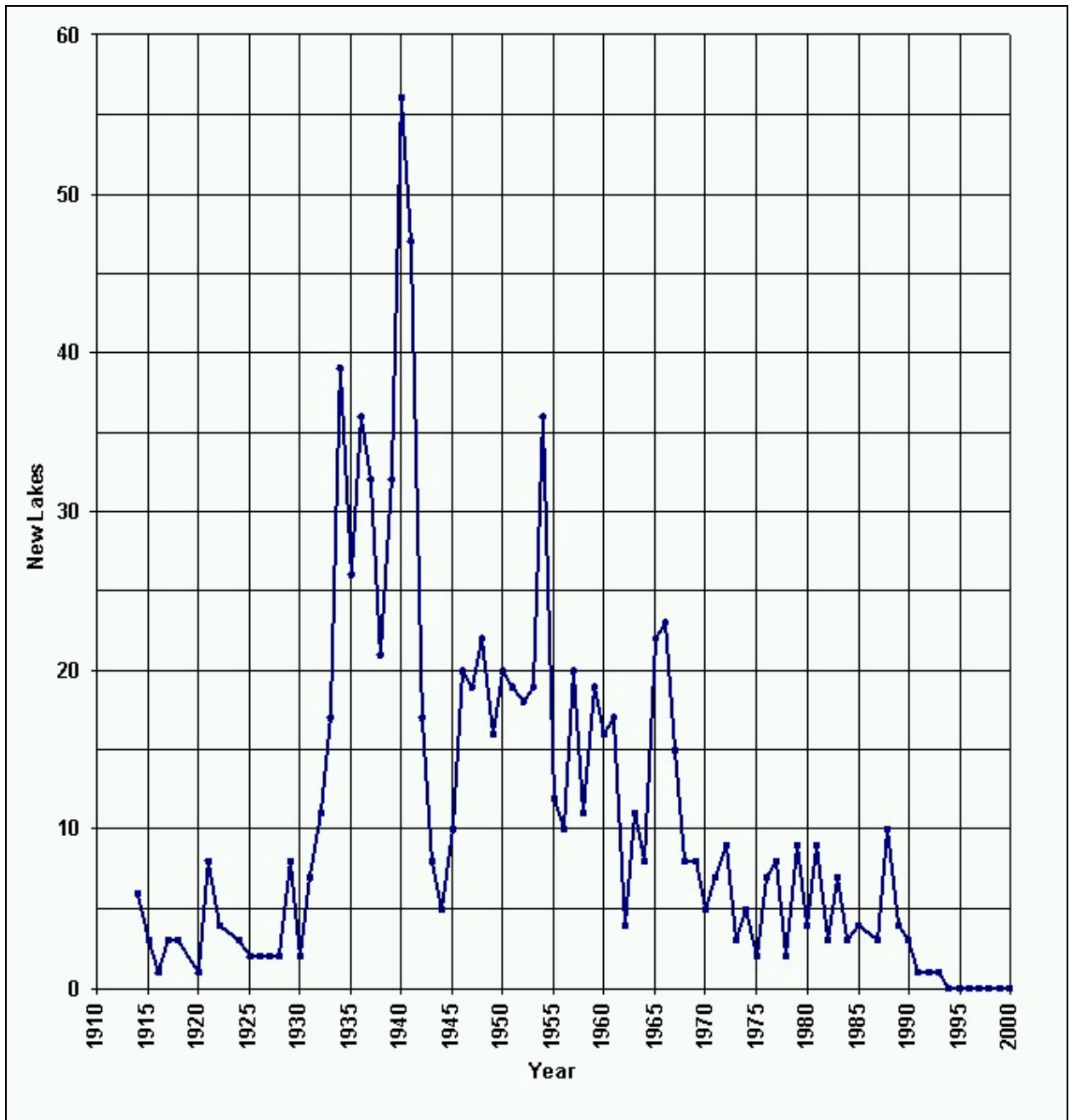


Figure 3. The Annual Number of High Lakes Stocked in Washington, by Year, 1909-2000.
 (Not the same as the number of lakes on a stocking cycle – see Table 2.)

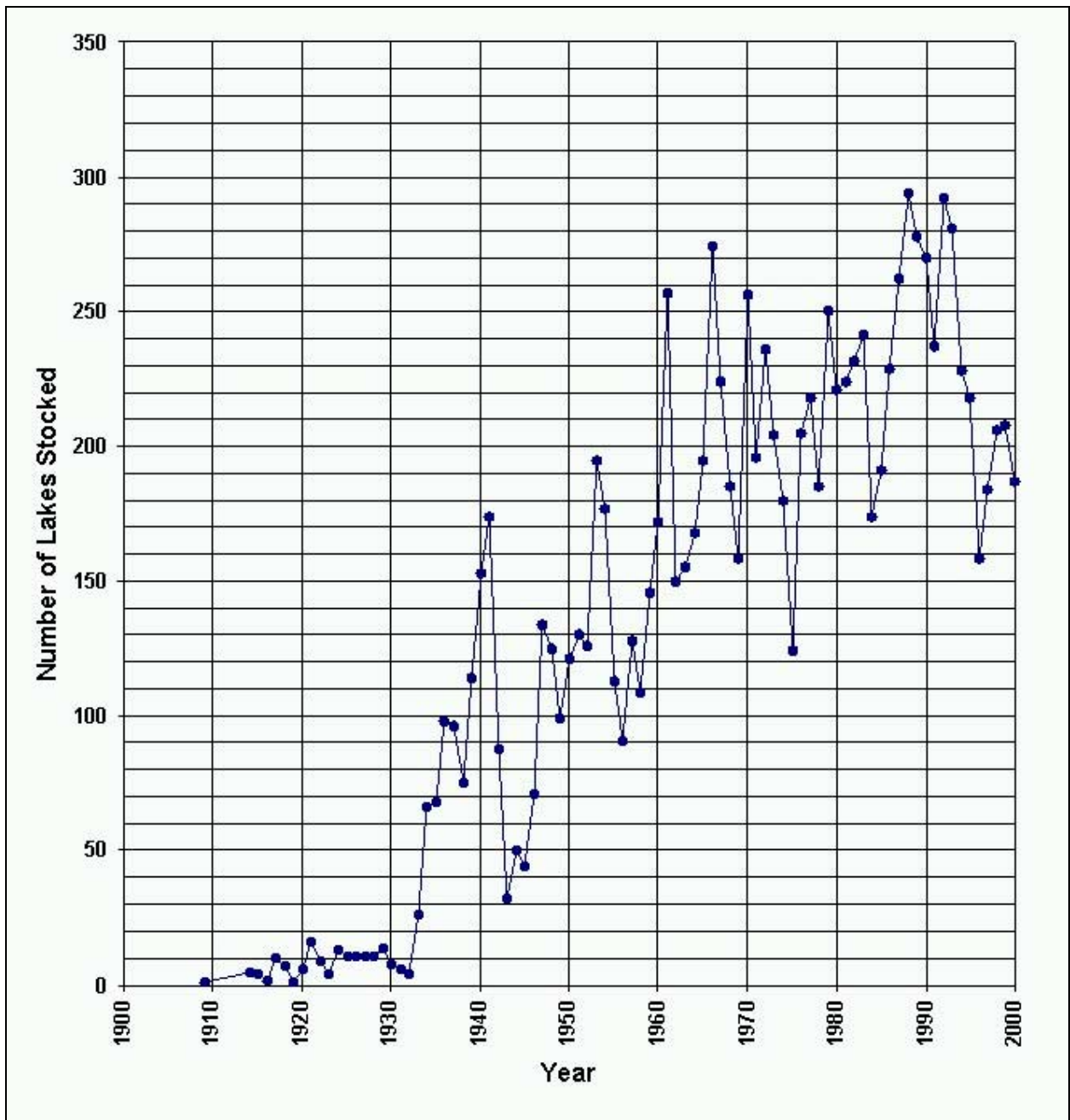


Figure 4. Mean Number of Fry Stocked Per Acre in Washington High Lakes, 1909 – 2000.

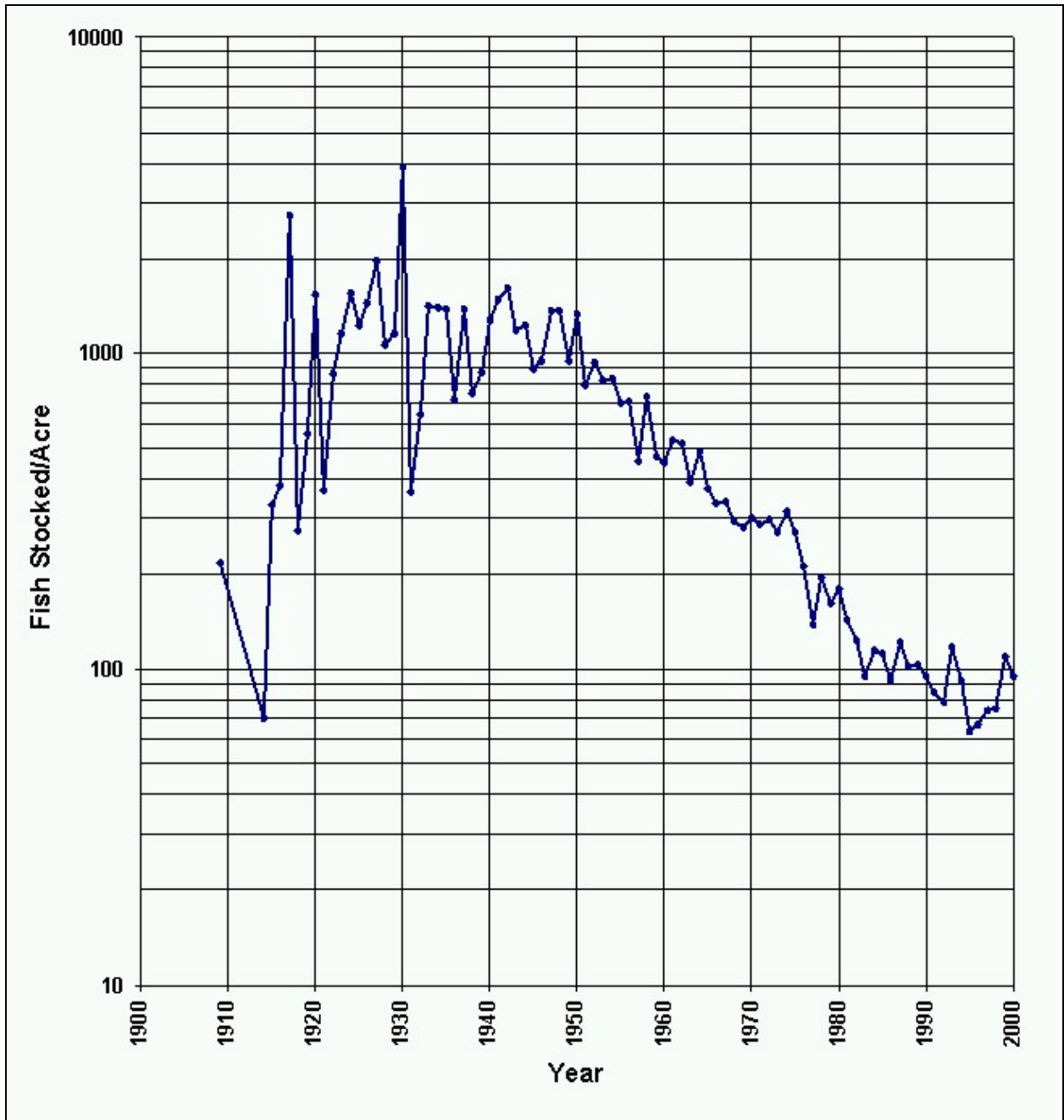
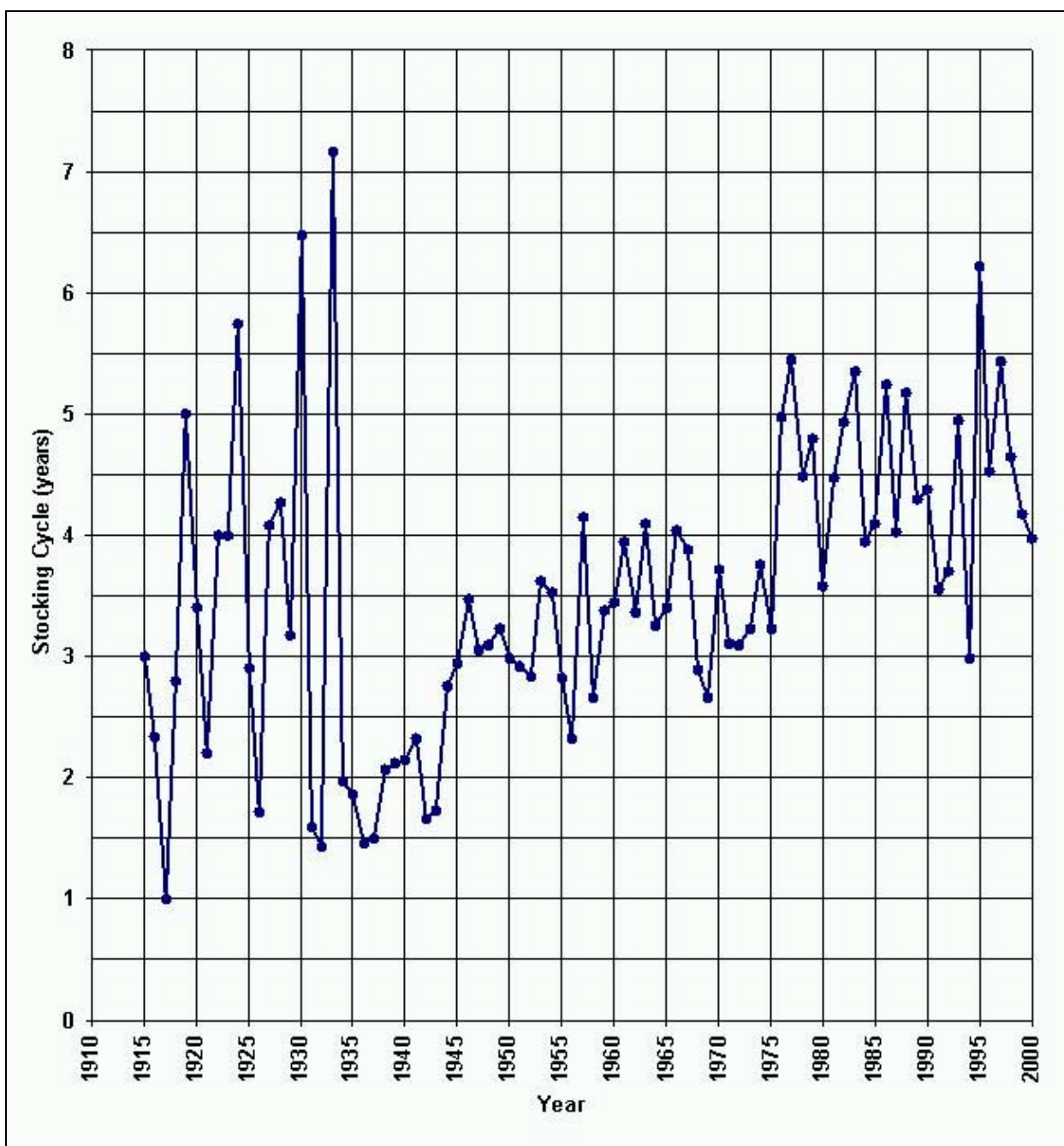


Figure 5. The Mean Number of Years Between Fry Introductions Among All Washington High Lakes Stocked Per Year, 1916 – 2000.



Other WDG district biologists have made comprehensive district surveys since these landmark reports, some of which have been similarly summarized in a technical report (Lucas 1989). An additional 32 lakes in the east central Cascades were surveyed and published under USFS contract (Deleray and Barbee 1992). Hundreds of high lake surveys have been made on the west side of the Cascades in WDFW administrative Region Four by Jim Johnston and Bob Pfeifer. Jim Cummins, Eric Anderson, and others have similarly made hundreds of surveys in the Chelan/Kittitas/Yakima Counties region. The data have not been published from most of these surveys, but the technical information has been used to develop individual lake by lake management plans. See Section 5.1 and Appendix C.

Development of Monitoring Procedures

A more focused approach to collection of angler trip report data began in the late 1970s. District fishery biologists prepared annual lists of lakes from which information was desired. These "survey lists" are still annually coordinated with sports clubs, particularly the Trail Blazers and Washington State Hi-Lakers (both based in Seattle). The High Lake Report card, initiated in the mid-1950s, was thoroughly revised in the mid-1980s, and the information collected is now entered into permanent databases (Section 5.2.1).

Database Development

Cooperative work over 10-15 years between the Trail Blazers, Inc., and WDG staff biologists has resulted in a high degree of knowledge of the historical stocking record of all managed lakes and their current stocking and trout reproductive status. Statewide cataloguing has also determined the relative number of lakes being actively managed for trout, or as fishless refugia for native flora and fauna (see Section 5.1, and the definition of a lake).

Some district managers have further organized their information on fishery monitoring, physical, chemical, and biological lake attributes, and trout age and growth into electronic databases (e.g., WDFW Fish Management Program 1994). The initial development of electronic databases for the high lake fishery program was accomplished by district fishery biologist Larry Brown in Wenatchee in the mid-1980s. (See Section 5.3.)

Stocking Procedures

Since 1972, techniques used to stock trout fry remained truck transport, backpacking, air drops by fixed-wing aircraft or helicopter, and horse packing. Only refinements in methods occurred, as described in Section 5.4.5. Use of oxygen in backpack and horse pack stocking significantly reduced hauling losses, and improved stocking precision with respect to managing for given fish densities. (Average losses in backpack containers documented by Trail Blazers, Inc. dropped from an average of 5.2% with 5-gallon cans to 2.3% with small, oxygenated containers.) Much greater attention to quality control was given to the number of fry actually stocked, and accuracy of final stocking records. This emphasis began in the early 1980s. A majority of high lakes are stocked using backpack methods (Section 5.4.5), most of which is conducted by the Trail Blazers. This club backpack stocks an average of 49.6 percent of the total number of high lakes stocked statewide.

Ecological Concern

Recognition of basic principles of lake carrying capacity and the effects of overstocking appear in Johnston (1973) and Williams (1972). These reports, and ensuing professional discussion within the agency, led to a general reduction in stocking rates and frequencies (Figures 4 and 5), depending on local lake conditions. Lakes occurring in alpine zones, with little soil development, difficult angler access, etc., were the lakes where stocking rates and frequencies were most commonly adjusted downward.

Experimentation on Biological Controls of Stunted Trout

The need to control overpopulation of trout or char in Washington's high lakes has long been recognized (WDG 1981). Limited experimentation with top predators and hybrid trout strains has occurred by local fishery managers since 1979 on a time-available basis. Much of this work has been in cooperation with Trail Blazers, Inc. Results to date, while promising in a few cases, remain unpublished. (See Section 5.7.2.)

Interagency Coordination

Meetings with land managers such as the US Forest Service and National Park Service became commonplace (annual events in some WDFW administrative regions) by the early 1980s. Issues of mutual concern were discussed, and largely resolved. WDFW coordinated and cooperated with the North Cascades National Park (NCNP) and its contracted researchers through all phases of studies on the effects of trout stocking in that park (see Section 5.9). Cooperative research on high lake stocking issues continues through the University of Washington.

Public Education

Articles of general interest relating to the high lake fishery were periodically published in the Department of Game's bi-monthly magazine. Recognition by the late 1980s of the need to address perceived public misunderstandings, and to direct mounting angler pressure to lakes and lake basins that could support higher use, led to cooperative development of an agency brochure on the high lake fishery (see Section 5.10.1). A concerted and successful effort was made to coordinate the brochure's content with US Forest Service wilderness managers, prior to its publication. Closely-related articles, radio programs, and agency website information were developed, largely through volunteered effort (see Section 5.10).

3. POLICIES, GOALS, AND OBJECTIVES

The Washington Fish and Wildlife Commission received its authority from the passage of Referendum 45 by the 1995 Legislature and public at the 1995 general election. The Commission is the supervising authority for the Department of Fish and Wildlife. With the 1994 merger of the former Department of Fisheries and Department of Wildlife, the Commission has comprehensive species authority as well.

While the Commission has several responsibilities, its primary role is to establish policy and direction for fish and wildlife species and their habitats in Washington, and to monitor the Department's implementation of the goals, policies and objectives established by the Commission. The Commission also classifies wildlife and establishes the basic rules and regulations governing the time, place, manner, and methods used to utilize or enjoy fish and wildlife. The current Goals, Policies, and Objectives (GPOs) of the Fish and Wildlife Commission have been published (WDFW 1995a; Appendix L).

The Department's mission is Sound Stewardship of Fish and Wildlife; one of its goals in pursuit of this mission is "Maximum fishing, hunting and non-consumptive recreational opportunities compatible with healthy, diverse fish and wildlife populations". In general, conservative utilization is the objective for naturally-produced, native fish and wildlife populations.

Additional guidance for the high lake program has been provided by the publication of the Wild Salmonid Policy (WSP) in 1997. The Commission GPOs and the WSP are largely directed at the stewardship and management of the state's native wildlife (reproducing vertebrate and invertebrate populations). The high lake fishery is almost entirely artificial, created for the sole purpose of providing recreational fishing opportunity in generally highly scenic, uncrowded surroundings. However, an explicit Goal of the Commission for its own activities is to "Maximize recreational opportunity for fish and wildlife constituents consistent with the preservation, protection, and perpetuation of the fish and wildlife resources" (WDFW 1995a). Goals specific to fish management include "providing for significant recreation opportunities through artificial propagation programs", and "maximiz(ing) fish recreation opportunities". Current WDFW high lake fishery management is consistent with these goals since it is designed to provide recreational fishing opportunity in ways that do not have significant negative impacts on native fish or other biota. This is explained in greater detail in subsequent sections of this report.

Commission Objectives under the Goal of maximizing fish recreation opportunities included implementing "balanced management strategies that provide for a variety of recreational activities including unique fishing opportunities (and) optimum harvest", among other elements. Most people would agree that catching or viewing high quality trout in a pristine alpine lake environment is a unique fishing experience. A related Objective directed the agency to "maintain maximum recreation through population manipulations with the use of stocked fish, partial treatments with rotenone, and other strategies in appropriate waters".

An additional Objective was to "conduct surveys to gather information on angler needs, desires, motivations and satisfactions". The most recent angler survey (WDFW 1996a) reaffirmed the large number of license-buyers who utilize the high lake fishery (see Section 4.0).

The published Wild Salmonid Policy, adopted by the Washington Fish and Wildlife Commission on December 5, 1997, makes no mention of the high lake stocking program (WDFW 1997). The bulk of the policy is directed at fishery, hatchery, and habitat programs and procedures that affect wild salmon and trout in streams, rivers, and estuaries. The only potential interaction between the high lake stocking program and wild, native salmonids in streams is addressed in the WSP under Ecological Interactions, Performance Standard 4: "All recommended guidelines for genetic diversity and ecological interactions

should apply in aquaculture programs where there is a likelihood of adverse interactions with wild populations”. Management of the current high lake program is sensitive to these potential interactions and guidelines (see Sections 5.4, 5.5, and 5.6).

4. FISHERY VALUE

"I learned these fishing skills almost entirely in the high Cascades. Up in that wild and remote country two or three of us would have whole lakes and streams to ourselves. It's the most ideal place to learn trout fishing that I know. Having learned the secrets of the trout, I acquired new confidence in my ability to survive in the mountains. My food supply was surely obtainable from the creeks and lakes; hence the fear of being lost and starving was not a factor in these trips." -- William O. Douglas - Of Men and Mountains (1950).

More than 175,000 license-buying anglers use Washington's high lakes annually (see Section 4.3 below). This figure does not include children and family members who fish high lakes, but do not purchase fishing licenses. For thousands of people, including several, if not all of the authors of this report, early fishing experiences in Washington's mountains were the first step in lifelong appreciation of wilderness and wildlife values (Plate 1). To quote a line from a recent public speech by co-author Mike Swayne, "there is something basic that connects a parent and a kid and a fish hitting a lure, and dancing on the end of the line, and then into the frying pan. Fish started me on a lifelong love affair with the lakes and the mountains that has affected my whole life for the better." For the authors of this report, as well as thousands of others, these experiences create future active defenders (Plate 2) of our land and wildlife heritage.

While much could be written on the incalculable values of Washington's high lake fishery, the following section provides more traditional measurable statistics on its economic value. In both cases, with proper management, both measurable and intangible values of this fishery can be maintained long into the future, without unacceptable or irreversible harm to other biological resources.

4.1 PROGRAMMATIC HATCHERY COST COMPARISON

The stocking component of the WDFW inland trout program consists primarily of "catchable" (9 to 12 inch) yearlings (usually rainbow), rainbow and cutthroat fry, and kokanee fry (Table 1). (In recent years purchased triploid trout weighing a pound or more have been added to the traditional program. The cost of these highly cultured trout accentuates the difference between lowland lake trout costs and high lake trout costs in the table of 1988 data below.) About \$3,615,000 was spent to culture trout for the inland trout program in 1988. Because of a year's hatchery care, catchable trout were most costly at \$0.52 apiece. Small, briefly-reared kokanee and trout fry released into lowland lakes averaged about ten cents apiece. Fry stocked into high lakes, which have the briefest period of care and feeding, cost about 1.3 cents apiece when averaged across all statewide hatcheries producing fry for the high lake program.

Table 1. Washington Department of Wildlife 1988* Statewide Trout Culture Costs by Fish Size Class

Size Group	Number Stocked	Total Cost	Cost per Fish
Catchable Trout	3,500,000	\$1,820,000	\$0.520
Low Lake Kokanee	8,700,000	\$817,800	\$0.094
Low Lake Trout Fry	10,400,000	\$977,600	\$0.094
High Lake Trout Fry	300,000	\$3,900	\$0.013

* Comparable statistics from recent years were not available when this report was prepared.



Plate 1. Quality wildlife experiences early in life enhance family relationships, and foster lifelong appreciation of natural resource values. Upper Greider Lake, Snohomish County, Washington.



Plate 2. A young angler holds a fish for a biologist surveyor to document unusual cryptic coloration of rainbow found in a high, clear, shallow lake in Snohomish County, Washington.

4.2 RELATIVE COST TO PROVIDE TROUT ANGLING OPPORTUNITY

The cost to administer high lake trout or char fisheries that are based on naturally-reproducing fish is almost zero. Some staff time is required to maintain file records on lakes with these populations, coordinate with landowners and other agencies on access to them, etc. This tends to be minimal when averaged across all such lakes. Most high lake administration costs are related to implementing the stocking program (which includes the cost of fish culture and stocking), coordinating monitoring of the overall fishery, and conducting baseline surveys on the few lakes that have not been surveyed.

It is instructive to compare the cost of providing an equal density of catchable (10 to 12 inch) trout in a typical lowland lake and a typical high lake. The cultural costs presented in the previous section are used in the example illustrated in Table 2. An initial stocking density of 280 trout per surface acre is used in this example to yield 125 fish per acre after two years in the lake. This stocking density is not often used in Washington high lakes today (Section 5.4.2), except in exceptionally rich lakes. However, experience has shown that this density of catchable trout is typically required in lowland lakes in western Washington in order to meet minimal early season catch rate objectives (WDFW 1994). Other assumptions in the example are 50 percent mortality of the fry stocked in the high lake in the first year (Donald and Alger 1986; Nelson 1987), and 10 percent in the second (Johnston 1973). In 1994 it cost \$74.38 to provide 125 catchable trout per acre, but a typical high lake can grow these same fish to beautiful condition (Plate 3) for \$1.29, or 1.7 percent of the cost for a lowland lake.

Table 2. Relative Cost to Stock 125 Catchable Trout Per Surface Acre of a Lowland Lake and a High Lake in Washington (1994 Values). Mortality Is Assumed To Be 50% To Age 1, And 10% To Age 2 In The High Lake

Lake Type	Density in (Year)	Cost per Fish	Total Stocking Cost
Lowland	125/ac (Year 0)	\$0.595	\$74.38
	280/ac (Year 0)		
High	140/ac (Year 1)	\$0.0046	\$1.29
	126/ac (Year 2)		

4.3 PARTICIPATION AND FISHERY VALUE

As mentioned above, an estimated 175,324 anglers fished Washington high lakes in 1994 (WDFW 1996a). This level of use leads to phenomenal overall fishery values, since high lake anglers made an average of 7.7 trips each, based on the 1995 angler survey (WDFW 1996a). No studies could be found that used the contingent value (willingness-to-pay) method of economic valuation to ask high lake anglers what they would be willing to pay to partake of this fishery. Most studies of freshwater angling arrive at values ranging from \$23 to \$60 for a day's "trout" fishing; this report uses an average of three recent studies on lowland lake and stream fisheries.



Plate 3. Phenomenal growth and condition was observed in Mount Whitney rainbow stocked at low density in a lake in the Wallace River (Skykomish River) drainage. The lake has been managed for a trout fishery since 1954. (22 August 1995) Mike Swayne photo.

The high lake fishery in Washington is worth an estimated \$67 to \$70 million annually (Table 3). An estimate of program costs and benefits was made in 1992 with the cooperation and assistance of Consulting Scientist Dr. Gerry Ring Erickson of the Washington State Hi-Lakers. Annual cost of labor, trout culture, and aircraft use in 1992 was about \$39,000 (Appendix G). Assuming an annual rate of inflation of 3.1 percent yields a program cost of \$41,455 in 1994, and a benefit / cost ratio of 1621:1. (If the 1997 purchase of a \$23,000 drop tank for the agency Beaver (see Section 5.4.5.3) is included in the cost and not amortized over its expected 30-year life, the ratio drops to 1043:1.)

Table 3. Washington High Lake Angler Effort Levels and Fishery Value, 1994 and 2001

	1994	2001
High Lake Anglers	175,324	182,666 ¹
Fishing Trips @ 7.7 days/angler ²	1,349,995	1,406,528
Value @ \$49.79/trip ³	\$67,216,251	\$70,031,029

¹ Assumes an annual increase of 4.19%; see Section 5.8.

² Source: WDFW (1996).

³ Arithmetic mean of three Contingency Valuation Method sources: Demirelli (1988); The Research Group (1991); Dalton et al. (1998).

It is clear from these values that the high lake fishery is one of, if not the most cost-effective fishery program administered by the WDFW. High lake fisheries that take advantage of the natural productivity of mountain lakes have long been recognized as being economical, as noted by Lindsey (1959): "Good fishing means good business; the dollar value of the airplane stocking program goes far beyond the fish in the creel."

4.4 ASSESSMENT AND RECOMMENDATIONS

The high lake fishery is phenomenally cost-effective. It provides some of the finest quality trout fishing opportunity in the state for a startlingly small amount of money. In 1992, the estimated cost to administer the program was 0.07 percent of the agency's \$53,593,000 biannual budget (Appendix G). While the cost of providing trout fishing opportunity in lowland lakes has risen significantly due to the general inability to maintain lowland lakes in an economical trout monoculture in western Washington (Fletcher 1976; Bradbury 1986; WDFW 1994), and due to the need to purchase even more costly triploid trout, the costs to maintain the high lake program have probably risen very little since 1994.

Johnston (1973) reported a total cost of \$400 to rehabilitate a 9 acre high lake on the Olympic National Forest. Even allowing for a 3 percent annual rate of inflation over 30 years, which results in a cost of \$943 per lake, a statewide program of just five lakes per year (one per district biologist, costing a total of about \$5000) would still result in a program benefit / cost ratio of 968:1, based on the 1994 program costs (\$67,216,251 / [\$41,455 + \$23,000 + \$5000].)

Recommendation #1: An updated and more detailed cost analysis of the high lake program in Year 2000 dollars should be conducted. Cost of staff labor and administration, fish culture, and stocking should be included.

Recommendation #2: A detailed cost estimate to conduct a typical high lake rehabilitation using both rotenone and Antimycin should be prepared. A technical memorandum should be prepared that can be used as a model by local managers to plan annual, or periodic high lake rehabilitations.

Recommendation #3: An annual program of rehabilitation of several high lakes should be implemented. A target of one lake per biologist per year is initially suggested. (See also Sections 5.7 and 5.8 Recommendations.) If the cost to rehab a high lake were ten times what it cost in 1973, the program would still be extremely cost-effective.

Recommendation #4: The agency should publish information on the cost-effectiveness of the high lake program as a form of outreach (Section 5.10).